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O'Neill

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(54) **SUPPORT OF DISPARATE ADDRESSING PLANS AND DYNAMIC HA ADDRESS ALLOCATION IN MOBILE IP**

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This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 12/099,026, filed on Apr. 7, 2008, now Pat. No. 8,559,411, which is a continuation of application No. 10/408,726, filed on Apr. 7, 2003, now Pat. No. 7,356,020.

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(51) **Int. Cl.**
H04J 3/24 (2006.01)
H04L 12/28 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04W 8/26*** (2013.01); ***H04W 8/08*** (2013.01); ***H04W 8/085*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04W 80/04
See application file for complete search history.

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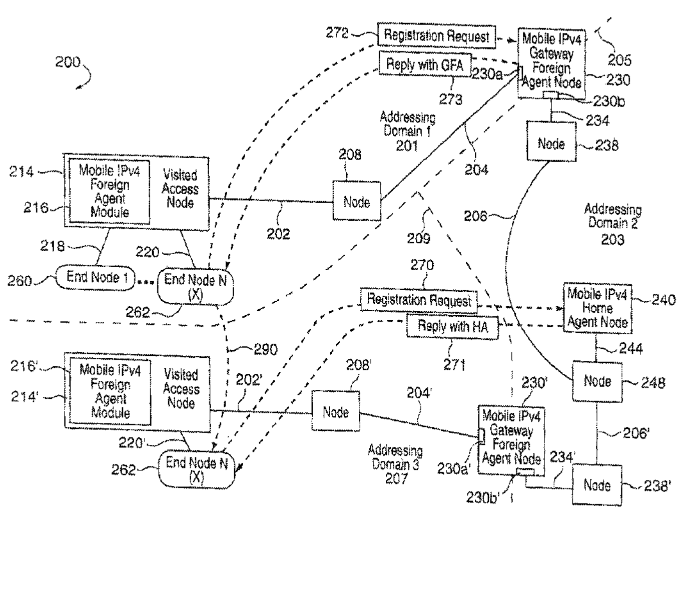
(57) **ABSTRACT**

Methods and apparatus for enhancing Mobile IP signaling and to support use of disparate addressing plans and dynamic Home Agent allocation in Mobile IP Regional Tunneling are described. The enhanced methods of signaling use an intermediate node, e.g., a Gateway Foreign Agent, straddling different addressing domains, when the signaling controls a process between the intermediate node and an upstream node. The specific intermediate node, its interfaces and upstream addresses can be dynamically selected. The Enhanced MIP signaling includes dynamic allocation of: a regional node at a Foreign Agent, the upstream address of a regional node by the regional node, a Home Agent for a regional node prior to dynamic allocation of the regional node. A method is supported to indicate to a Mobile Node that a dynamically allocated regional node has become invalid triggering enhanced MIP signaling dynamically allocating a new regional node and upstream interface address.

22 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

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H04W 8/06	(2009.01)
H04W 80/04	(2009.01)
H04W 88/16	(2009.01)

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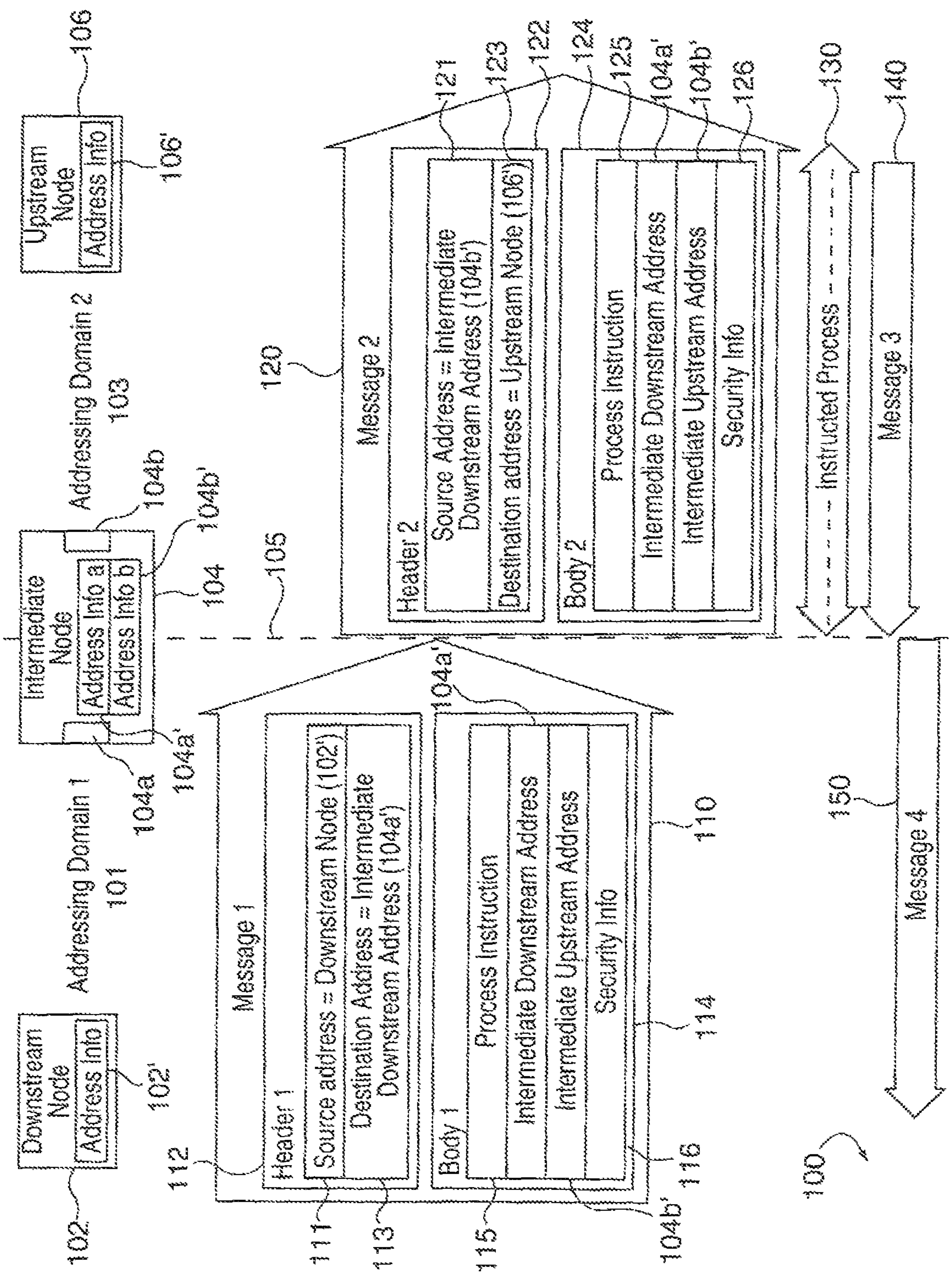


Downstream Node
Address Info
102
102'
Addressing Domain 1
101
Intermediate Node
Address Info a
Address Info b
104
104a
104a'
104b
104b'
105
Addressing Domain 2
103
Upstream Node
Address Info
106
106'
Message 1
110
112
Header 1
Source address = Downstream Node (102')
Destination Address = Intermediate Downstream Address (104a')
111
113
Body 1
Process Instruction
Intermediate Downstream Address
Intermediate Upstream Address
Security Info
114
115
116
Message 2
120
Header 2
Source Address = Intermediate Downstream Address (104b')
Destination address = Upstream Node (106')
121
122
123
Body 2
Process Instruction
Intermediate Downstream Address
Intermediate Upstream Address
Security Info
124
125
126
Instructed Process
130
Message 3
140
Message 4
150
100

FIG. 1

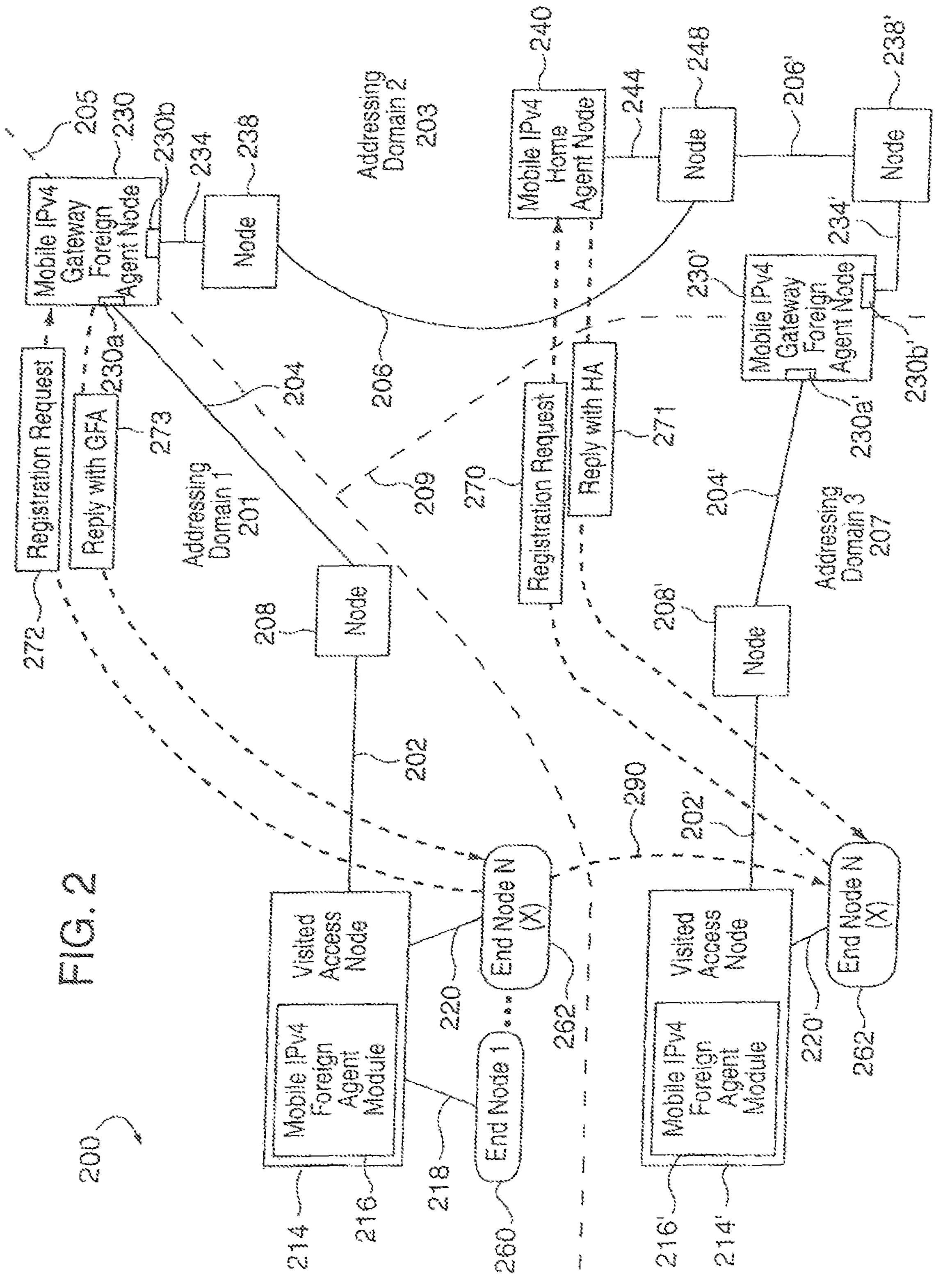
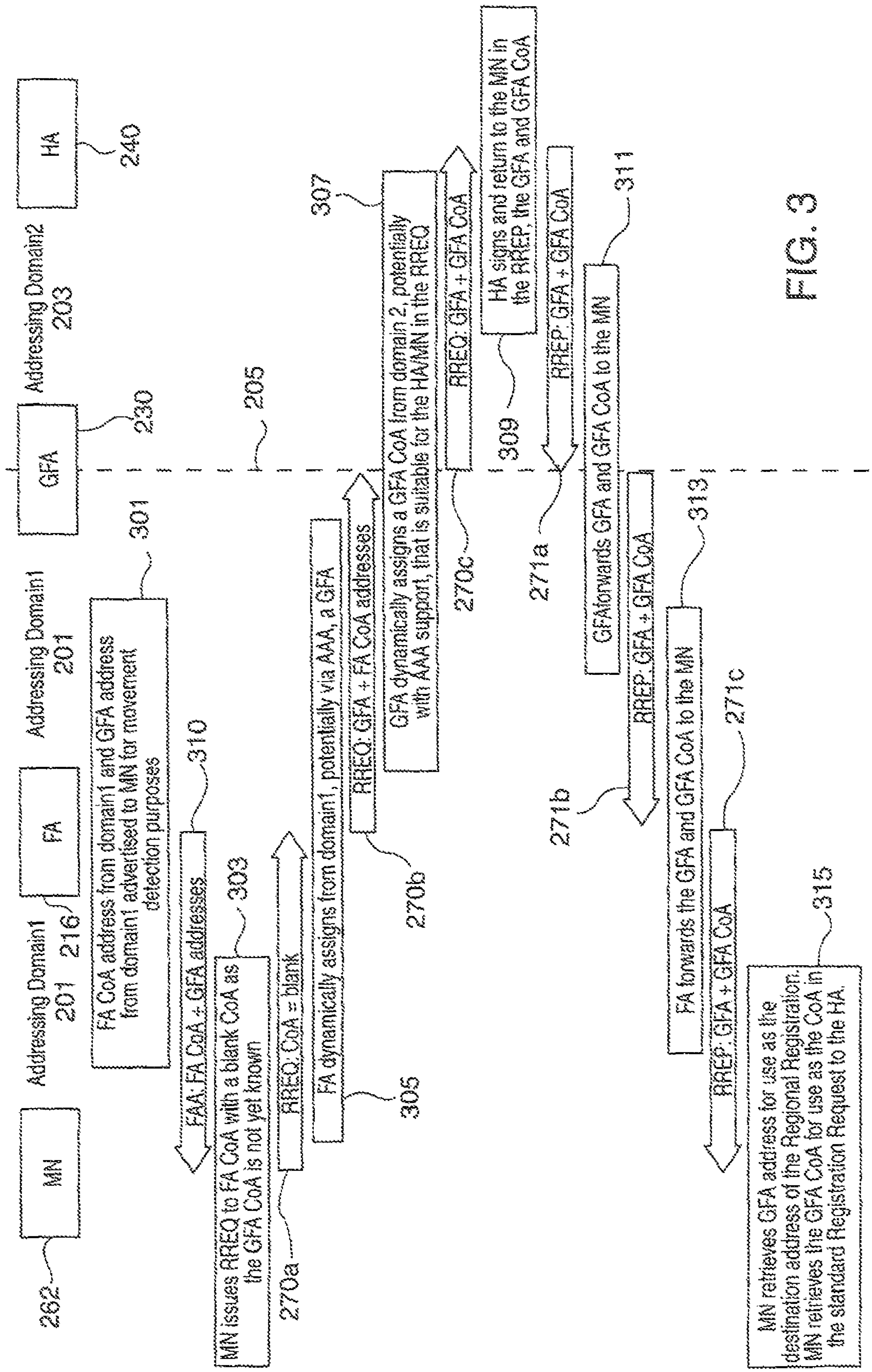

200
205
Mobile IPv4 Gateway Foreign Agent Node
230
230a
230b
234
Node
238
Addressing Domain 2
203
Mobile IPv4 Home Agent Node
240
244
Node
248
206'
Node
238'
234'
Mobile IPv4 Gateway Foreign Agent Node
230'
230a'
230b'
Registration Request
272
Reply with GFA
273
Addressing Domain 1
201
204
206
209
Registration Request
270
Reply with HA
271
204'
Addressing Domain 3
207
Node
208
Node
208'
202
202'
290
Visited Access Node
Mobile IPv4 Foreign Agent Module
214
216
End Node N (X)
220
262
End Node 1
218
260
Visited Access Node
Mobile IPv4 Foreign Agent Module
216'
214'
End Node N (X)
220'
262

FIG. 2



262
MN
Addressing Domain1
201
216
FA
Addressing Domain1
201
GFA
230
Addressing Domain2
203
HA
240
205
301
FA CoA address from domain1 and GFA address from domain1 advertised to MN for movement detection purposes
310
FAA: FA CoA + GFA addresses
303
MN issues RREQ to FA CoA with a blank CoA as the GFA CoA is not yet known
270a
RREQ: CoA = blank
305
FA dynamically assigns from domain1, potentially via AAA, a GFA
270b
RREQ: GFA + FA CoA addresses
307
GFA dynamically assigns a GFA CoA from domain 2, potentially with AAA support, that is suitable for the HA/MN in the RREQ
270c
RREQ: GFA + GFA CoA
309
HA signs and return to the MN in the RREP, the GFA and GFA CoA
271a
RREP: GFA + GFA CoA
311
GFAforwards GFA and GFA CoA to the MN
271b
RREP: GFA + GFA CoA
313
FA forwards the GFA and GFA CoA to the MN
271c
RREP: GFA + GFA CoA
315
MN retrieves GFA address for use as the destination address of the Regional Registration. MN retrieves the GFA CoA for use as the CoA in the standard Registration Request to the HA.

FIG. 3

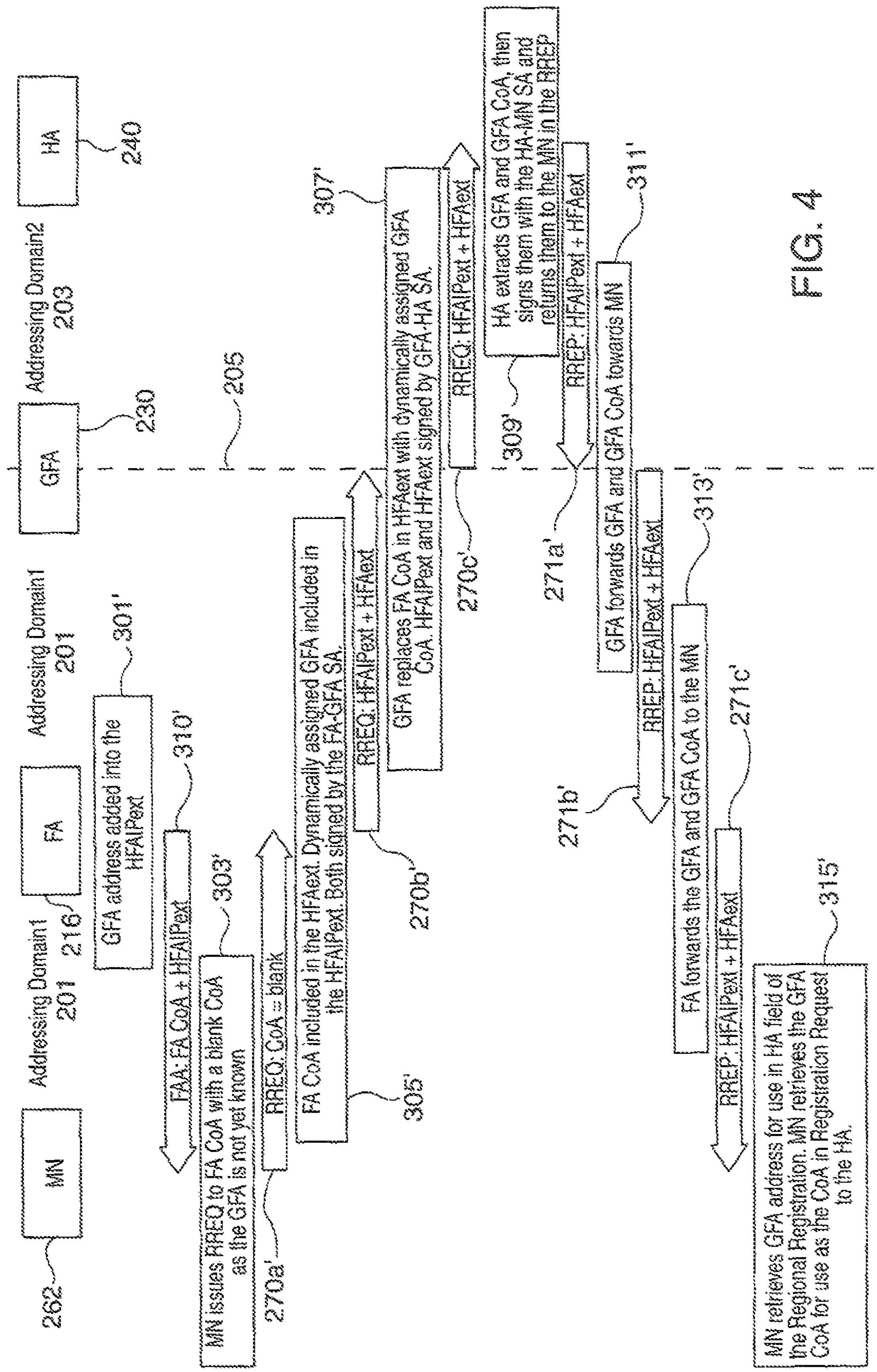

MN
262
Addressing Domain1
201
FA
216
Addressing Domain1
201
GFA
230
Addressing Domain2
203
HA
240
205
GFA address added into the HFAIPext
301'
FAA: FA CoA + HFAIPext
310'
MN issues RREQ to FA CoA with a blank CoA as the GFA is not yet known
303'
RREQ: CoA = blank
270a'
FA CoA included in the HFAext. Dynamically assigned GFA included in the HFAIPext. Both signed by the FA-GFA SA.
305'
RREQ: HFAIPext + HFAext
270b'
GFA replaces FA CoA in HFAext with dynamically assigned GFA CoA. HFAIPext and HFAext signed by GFA-HA SA.
307'
RREQ: HFAIPext + HFAext
270c'
HA extracts GFA and GFA CoA, then signs them with the HA-MN SA and returns them to the MN in the RREP
309'
RREP: HFAIPext + HFAext
271a'
GFA forwards GFA and GFA CoA towards MN
311'
RREP: HFAIPext + HFAext
271b'
FA forwards the GFA and GFA CoA to the MN
313'
RREP: HFAIPext + HFAext
271c'
MN retrieves GFA address for use in HA field of the Regional Registration. MN retrieves the GFA CoA for use as the CoA in Registration Request to the HA.
315'

FIG. 4

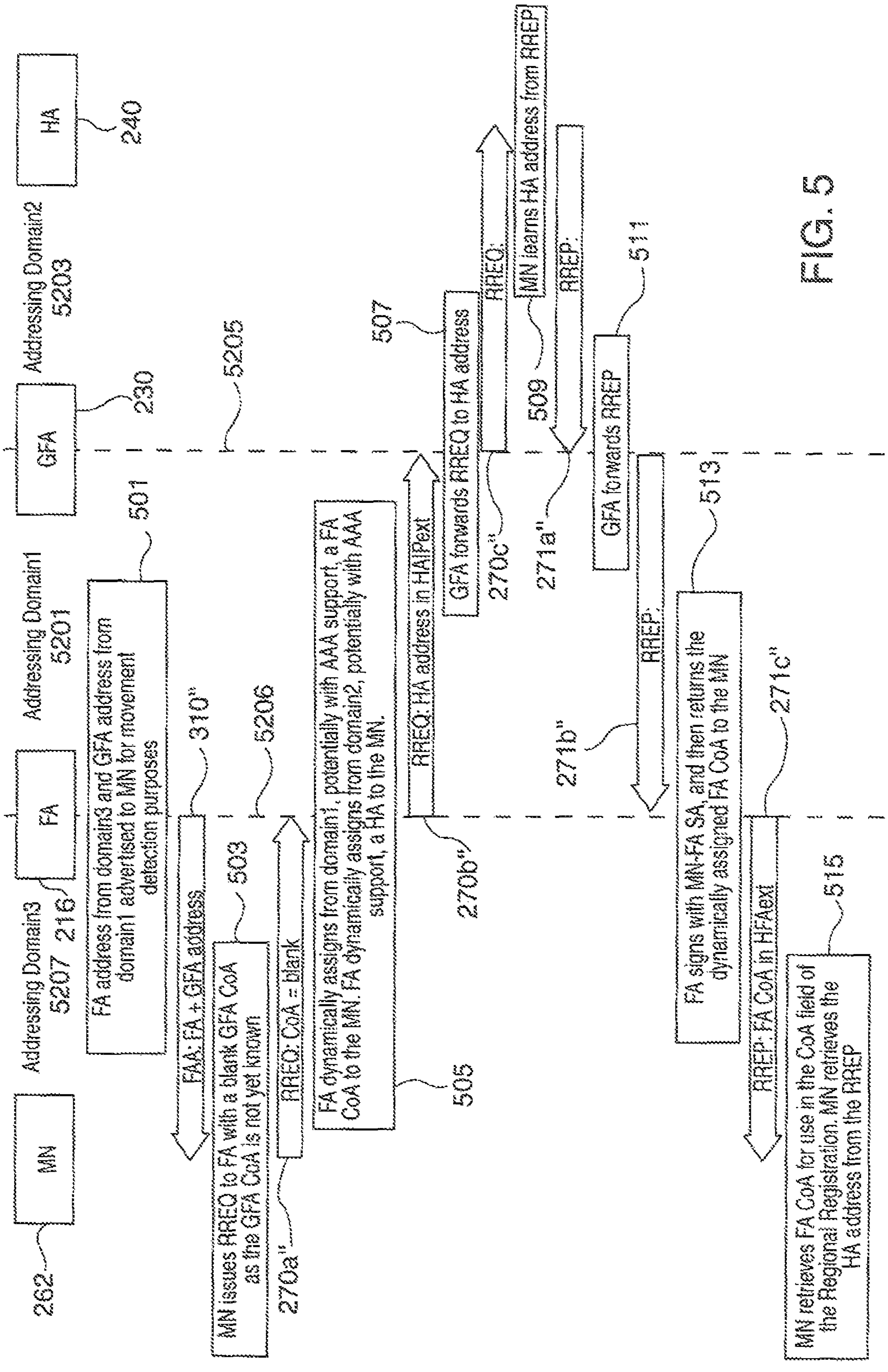

MN
262
Addressing Domain3
5207
FA
216
Addressing Domain1
5201
GFA
230
Addressing Domain2
5203
HA
240
FA address from domain3 and GFA address from domain1 advertised to MN for movement detection purposes
501
FAA: FA + GFA address
310"
5206
5205
MN issues RREQ to FA with a blank GFA CoA as the GFA CoA is not yet known
503
RREQ: CoA = blank
270a"
FA dynamically assigns from domain1, potentially with AAA support, a FA CoA to the MN. FA dynamically assigns from domain2, potentially with AAA support, a HA to the MN.
505
RREQ: HA address in HAIPext
270b"
GFA forwards RREQ to HA address
507
270c"
RREQ:
MN learns HA address from RREP
509
RREP:
271a"
GFA forwards RREP
511
RREP:
271b"
FA signs with MN-FA SA, and then returns the dynamically assigned FA CoA to the MN
513
RREP: FA CoA in HFAext
271c"
MN retrieves FA CoA for use in the CoA field of the Regional Registration. MN retrieves the HA address from the RREP
515

FIG. 5

SUPPORT OF DISPARATE ADDRESSING PLANS AND DYNAMIC HA ADDRESS ALLOCATION IN MOBILE IP

RELATED APPLICATIONS

The present application is a continuation of pending U.S. patent application Ser. No. 12/099,026, now U.S. Pat. No. 8,559,411, filed on Apr. 7, 2008, titled SUPPORT OF DISPARATE ADDRESSING PLANS AND DYNAMIC HA ADDRESS ALLOCATION IN MOBILE IP, and which claims the benefit of the filing date of U.S. patent application Ser. No. 10/408,726, now U.S. Pat. No. 7,356,020, filed on Apr. 7, 2003, titled SUPPORT OF DISPARATE ADDRESSING PLANS AND DYNAMIC HA ADDRESS ALLOCATION IN MOBILE IP, and which claims the benefit of the filing date of U.S. Provisional Patent Application Ser. No. 60/370,836 filed Apr. 8, 2002, titled "METHODS AND APPARATUS FOR THE SUPPORT OF DISPARATE ADDRESSING PLANS AND DYNAMIC HA ADDRESS ALLOCATION IN MOBILE IP REGIONAL TUNNELING." Each of the preceding identified US patent applications are hereby expressly incorporated by reference in their entirety.

BACKGROUND

For the purpose of understanding the invention it is useful to have a basic understanding of Mobile IP. Mobile IP (v4/v6), also indicated as MIPv4 [MIPv4] and MIPv6 [MIPv6], enables a mobile node (MN) to register its temporary location indicated by a care-of-address (CoA) to its Home Agent (HA). The HA then keeps a mapping (also called a binding) between the MN's permanent address, otherwise called Home Address (HoA), and the registered CoA so that packets for that MN can be redirected to its current location using IP encapsulation techniques (tunneling).

The CoA used by a MN can be an address that belongs to a Foreign Agent (FA) when MIPv4 is used or, in MIPv4 and MIPv6, it can be a temporarily allocated address to the MN itself in which case is called a collocated care-of-address (CCoA).

The concepts and solutions described here are applicable to both MIPv4 and MIP unless otherwise mentioned.

Regional tunneling (REGTUN) is one technique sometimes used in conjunction with Mobile IP. This approach uses a Gateway Foreign Agent (GFA) between the FA and the HA to improve MIP signaling. Specifically, the MN can register the local GFA CoA into the HA using an MIP registration with the HA that is routed via the GFA. Then each binding update under the same GFA goes just to the GFA instead of the HA, and changes the FA CoA for the GFA. The GFA switches the GFA CoA traffic for the specific HoA into the FA CoA matching that HoA and GFA CoA. The GFA update is a regional registration and it avoids having to refresh the HA on each hand-off which is a bandwidth and latency gain because the HA could be a very distant node from the FA/GFA.

The problem with this draft (http://www.ietf.org/proceedings/01dec/I-D/draft-ietf-mobileip-reg-tunnel-05.txt) is that the signaling scheme assumes that the two addressing schemes are the same either side of the GFA, and no support is enabled for dynamic HA allocation, both of which are common requirements in MIP. Therefore, a need exists for apparatus and methods that will support disparate addressing plans and dynamic HA address allocation in MIP signaling.

SUMMARY OF THE INVENTION

The present invention is directed to methods and apparatus establishing communications sessions and, more particularly, to enhanced methods of performing signaling through an intermediate node that straddles different addressing domains, when that signaling is trying to control a process undertaken between the intermediate node and an upstream node. Various methods for enhancing Mobile IP discovery of the IP addresses of Mobile IP nodes, and the subsequent configuration of Mobile IP forwarding tunnels is then described.

In accordance with one feature of the present invention, rather than allow a downstream node to use the address of the downstream interface on an intermediate node, that is in the same addressing domain as the downstream node, for undertaking a process with the upstream node, in accordance with the present invention, the address of the upstream interface of the intermediate node, that is in the same addressing domain as the upstream node, is instead selected to be the address on the intermediate node for the communications process with the upstream node. This ensures that the upstream node can communicate with the intermediate node for the identified process, even when the two addressing domains are different and the downstream interface of the intermediate node is not reachable from the upstream node. In the case of Mobile IP, the communications process is the MIP tunneling between, for example, an upstream Home Agent and an intermediate regional node such as a Gateway Foreign Agent, which is configured using a MIP Registration Request message from the downstream foreign agent. This then ensures that the tunnel be correctly set-up even when private addresses are used between the foreign agent and the regional node whilst public addresses are used between the regional node and the home agent. Existing Mobile IP signaling instead uses a single piece of information to identify the address of the regional node and the process address for the upstream node with the regional node, which fails in the case of distinct addressing domains on either side of the regional node.

Further, in accordance with this invention, the specific intermediate node, as well as the upstream interface and therefore the upstream address at that intermediate node, can all be dynamically selected during the signaling phase, based on information about the type of communications process being set-up, the entity and its location that is requesting that it be set-up, and the type and location of the upstream node. This novel feature of the invention is particularly useful for supporting multiple intermediate nodes in a domain, each of which serves a subset of all the downstream nodes in a domain, and for ensuring that the selected upstream interface of the selected intermediate node is in the same addressing domain as the upstream node. In the specific case of Mobile IP, the present invention enables the regional node to be dynamically allocated at the foreign agent, optionally with the assistance of the Authentication, Authorization and Accounting (AAA) system, and the upstream address of the regional node to be dynamically allocated by the regional node itself, optionally again with assistance from the AAA system. This then avoids all Mobile Nodes having to be configured with, or discover, a table that lists all possible HAs and the associated regional node and upstream interface at that regional node that matches that particular Home Agent. Existing MIP signaling relies on the address of the regional node being known at the foreign agent, and optionally communicated to the Mobile Node in advance of the Registration signal being sent from the Mobile Node, that will traverse the regional node towards the Home Agent. This clearly does not facilitate dynamic allocation of the regional node, nor the dynamic allocation of the associated upstream interface address.

Inventive methods, in accordance with the present invention, are also described for dynamically allocating the Home Agent in advance of dynamically allocating the associated regional node, and for communicating the addresses of these dynamically allocated nodes to the other Mobile IP nodes that need that address information for subsequent Mobile IP signaling. The address of the HA should be communicated to the regional node so that the regional node can forward the Registration message to that HA and invoke the tunnel building process between the HA and the regional node. Existing MIP signaling for the regional node does not support dynamic allocation of a HA.

Another novel method, in accordance with the present invention, is described for indicating to a Mobile Node when the allocated regional node, that was dynamically allocated to the Mobile Node, becomes invalid, triggering another MIP signaling phase from the Mobile Node to dynamically allocate a new regional node and associated upstream interface address. This method is in contrast to existing MIP signaling which cannot accommodate a dynamically allocated regional node.

Numerous additional features and benefits of the present invention will be apparent in view of the Figures and detailed description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates two addressing domains; the generic downstream, intermediate and upstream nodes; and the signals employed to invoke the process between the upstream node and the upstream interface of the (intermediate) node.

FIG. **2** illustrates a diagram of an exemplary network supporting a Mobile IP Regional node and the Mobile IP signals used to invoke and manage the tunnel between the Home Agent and the regional node, as well as the tunnel between the regional node and the foreign agent.

FIG. **3** illustrates the MIP signaling flow for the dynamic allocation of the regional node, and the interface on that regional node, in the case of a Gateway Foreign Agent, as well as the discovery of a change of regional node.

FIG. **4** illustrates the MIP extensions used to carry the dynamically allocated GFA and GFA CoA to the necessary MIP nodes.

FIG. **5** illustrates the dynamic allocation of a Home Agent in the presence of a regional node, as well as the MIP signaling changes when the generic intermediate node is additionally a foreign agent that straddles two addressing domains.

DESCRIPTION OF THE INVENTION

The methods and apparatus of the present invention are directed to a number of procedures to enable the IP signaling layer (MIP or similar mechanisms) to better support the existence of a regional node.

FIG. **1** shows an overall communication domain **100** including an exemplary addressing domain 1 **101** and an exemplary addressing domain 2 **103**. Addressing domain 1 **101** includes a downstream node **102**; addressing domain 2 **103** includes an upstream node **106**. An intermediate node **104** is located on a boundary **105** separating addressing domain 1 **101** from addressing domain 2 **103**. Intermediate node **104** includes two addressing interfaces: addressing domain 1 interface **104***a* and addressing domain 2 interface **104***b*. Intermediate node **104** also includes address information **104***a*' associated with interface **104***a* and address information b **104***b*' associated with interface **104***b*. Downstream node **102** may be, for example, a visited access node; intermediate node **104** may be, for example, a MIP Gateway Foreign Node; upstream node **106** may be, for example, a Mobile IP Home Agent.

The downstream node **102** and the intermediate node **104** have interfaces with addresses, **102'** and **104***a*', respectively, from the addressing domain 1 **101**, such that messages can flow from the downstream node **102** to the downstream interface of the upstream node **104***a*. The upstream node **106** and the intermediate node **104** have interfaces with addresses, **106'** and **104***b*', respectively, from the addressing domain 2 **103**, such that messages can flow from the upstream interface of the intermediate node **104***b* to the upstream node **106**.

FIG. **1** further shows instructed processes **130**, as illustrated by the dashed bi-directional arrows between the upstream node **106** and the intermediate node **104**. The process **130** may be, for example, the invocation and management of a tunnel.

When the addressing domain 1 **101** and addressing domain 2 **103** are independent addressing domains, such that reachability is not supported between those addressing domains, then messages are not generally able to flow between the upstream node **106** and the downstream interface of the intermediate node **104***a*, such that any process **130** undertaken between the upstream node **106** and the intermediate node **104**, needs to be undertaken using the interface address **104***b*'.

To invoke such a process **130** from the downstream node **102**, or any node further downstream of the downstream node **102**, a message 1, **110**, is first sent from the downstream node **102** to the intermediate node **104** using interface **104***a*, possibly as a result of an incoming message from a node further downstream of the downstream node **102**. Message 1, **110**, includes a message header **112** which includes source and destination addresses, **111**, **113**, respectively, equal to the addresses of the downstream node **102'** and the downstream interface of the intermediate node **104***a*', respectively. Message 1, **110**, also includes a message body **114** that includes an instruction **115** to invoke the process **130** between the upstream node **106** and the intermediate node **104**. The Message body 1, **114**, also includes an information element indicating the intermediate node downstream address **104***a*' that has been dynamically allocated at the downstream node **102**. The message body 1 **114** may additionally contain the intermediate node upstream address **104***b*', which without loss of generality may be empty. The information in the message body 1 **114** is typically signed by the downstream node **102** as represented by security information **116** to prevent its contents being manipulated by an attacker situated between the downstream node **102** and the intermediate node **104**.

To further invoke such a process **130** from the intermediate node **104**, a message 2, **120**, is first sent from the upstream interface of the intermediate node **104***b* to the upstream node **106**. Message 2, **120**, includes a message 2 header **122** which includes source and destination addresses, **121**, **123**, respectively, equal to the addresses of the intermediate node upstream interface **104***b*' and the upstream node **106'**, respectively. Message 2, **120**, also includes a message 2 body **124** that includes an instruction **125** to invoke the process **130** between the upstream node **106** and the intermediate node **104** that was obtained from message 1, **110**. The Message body **2**, **124**, also includes an information element indicating the intermediate node downstream address **104***a*' that has been dynamically allocated at the downstream node **102**. The message body 2 **124** also includes the intermediate node upstream address **104***b*', which was generated at the intermediate node **104**. The information in the message body 2 **124** is typically signed, as indicated by security information **126**, by the intermediate node **104** to prevent its contents being manipulated by an attacker situated between the intermediate node **104** and the upstream node **106**. Without loss of generality, the generation of the upstream address **104***b*' at the intermediate node **104** can be undertaken in a number of ways. Firstly, it can be obtained from message body 1, **114**, if the intermediate node upstream address **104***b*' was dynamically allocated at the downstream node **102** along with the downstream address **104***a*'. Secondly, the intermediate node upstream address **104***b*'can be dynamically allocated at the intermediate node **104** itself and inserted into message body 2 **124** instead of any empty or default value passed in message body 1, **114**. Thirdly, the upstream address on the intermediate node **104***b*' can be requested and obtained by either the downstream and/or intermediate nodes **102**,**104** from an external policy server such as an Authentication, Authorization and Accounting Server.

The upstream node **106** can then invoke the process **130** with the upstream address **104***b*' of the intermediate node **104**. In addition, messages **140** and **150** are then used to carry the dynamically allocated addresses **104***a*' and **104***b*' back to the downstream node **102** and to any nodes further downstream from the downstream node **102** that needs those addresses **104***a*', **104***b*' to repeatedly invoke the process **130** via that intermediate node **104**.

This sequence ensures that the process **130** from the upstream node **106** does not use the downstream address **104***a*' of the intermediate node **104** which in the case of separate addressing domains may not be reachable.

The application of the above sequence will now be explained, without loss of generality, for the specific case of the downstream node **102** being a MIP foreign agent, the upstream node **106** being a MIP home agent, the intermediate node **104** being a MIP regional node such as Gateway Foreign Agent, and the process **130** being the construction of a MIP tunnel between the MIP Home Agent and the Gateway Foreign Agent on request from a Mobile Node.

FIG. **2** shows an exemplary communications network **200** including 3 addressing domains: addressing domain 1 **201**, addressing domain 2 **203**, and addressing domain 3 **207**. Boundary line **205** separates addressing domain 1 **201** from addressing domains **203** and **207**. Boundary line **209** separates addressing domain 2 **203** from addressing domain 3 **207**.

The exemplary communications network **200** comprises a visited access node **214**, e.g. a visited access router, including a Mobile IP foreign agent (FA) **216**, a Mobile IP Gateway foreign agent (GFA) **230**, and a Mobile IP Home agent (HA) **240**. The GFA **230** is located on the boundary **205** between addressing domain 1 **201** and addressing domain 2 **203**. Within addressing domain 1 **201**, the GFA **230** is connected to the FA **216** via a node **208** and links **204** and **202**. Within addressing domain 2 **203**, the GFA **230** is connected to the HA **240** through nodes **238** and **248** via links **234**, **206** and **244**. Link **234** couples GFA **230** to node **238**; link **206** couples node **238** to node **248**; link **244** couples node **244** to HA **240**. The GFA **230** therefore has two different interfaces, such that a GFA interface **230***a* on link **204** has an address from the same addressing domain 1 **201** as that of the FA **216** interface connected to link **202**. In contrast, a GFA **230** interface **230***b* attached to link **234** has an address allocated from the same addressing domain 2 **203** as the address allocated to the interface on the HA **240** connected to link **244**. In the communications network **200** it can be seen that no path exists between the HA **240** and the FA **216** that does not traverse the GFA **230**. In addition, the addresses from the addressing domain 1 **201** shared by the FA **216** and the GFA **230** are not routable from the addresses from the addressing domain 2 **203** shared by the HA **240** and the GFA **230**.

Exemplary end node 1 **260** and exemplary end node N (X) **262** are coupled to the communications network **200** through the visited access node **214**. Specifically, links **218**, **220** couple end nodes **260**, **262**, respectively, to visited access node **214** with its FA **216**. The end nodes **260**, **262** may be, for example, mobile nodes or mobile terminals. Many such end nodes **260**, **262** and visited access nodes **214** will typically exist in communications network **200**, along with a smaller number of GFAs **230**. Each such GFA **230** will be assigned to a subset of the visited access nodes **214**, and advertised to the end nodes **260**, **262** which contain MIP Mobile Node software. The movement of the end nodes **260**, **262** between visited access nodes **214** can eventually result in the end node receiving a newly advertised GFA **230** address, this address being that of the interface **230***a* connected to link **204** which can be known to the FA **216**. Whilst the exemplary Mobile Node (MN) N (X) **262** receives the same GFA **230** address from any FA **216**, the MN **262** can issue MIP Regional Registration messages **272** towards the GFA **230**, potentially via the FA **214**. This message **272** updates the Care of Address in the GFA **230** for the home address of the MN **262**, this care of address being either the FA **216** address or the address of the MN **262**, such that a tunnel can be constructed between the GFA **230** and the Care of address. The Registration Reply message **273** is then returned to the MN **262** visiting the same MIP nodes as that visited by the Registration message.

In order to further explain variations of the present invention, the connectivity between addressing domain 3 **207** and addressing domain 2 **203** is described below. Dotted arrow line **290** represents the transition of exemplary end node N (X) **262** from addressing domain 1 **201** to addressing domain 3 **207**. Addressing domain 3 **207** includes a visited access node **214'**, with a mobile IP Foreign agent module **216'**, and node **208'**. Link **202'** couples FA **216'** to node **208'**. Node **208'** is coupled to a MIP Gateway Foreign Agent Node **230'** via link **204'**. Addressing domain 2 **203** further comprises node **238'** which is coupled to node **248** via link **206'**. Node **238'** is also coupled to GFA **230'** via link **234'**.

MIP Gateway Foreign Agent Node **230'** is located on the boundary, indicated by dashed line **209**, between addressing domain 2 **203** and addressing domain 3 **207**. GFA **230'** includes interfaces **230'***a* and **230'***b*. The GFA **230'** therefore has two different interfaces, such that the GFA interface **230'***a* on link **204'** has an address from the same addressing domain 3 **207** as that of the FA **216'** interface connected to link **202'**. In contrast, the GFA **230'** interface **230'***b* attached to link **234'** has an address allocated from the same addressing domain 2 **203** as the address allocated to the interface on the HA **240** connected to link **244**.

When however, the MN **262** receives a new GFA **230'** address from the FA **216'**, then the MN **262** knows that no MIP tunnel exists between the Home Agent **240** of the MN **262** and the GFA **230'** and, in accordance with the invention, therefore issues a MIP Registration message **270** towards the HA **240**, that is forwarded via the FA **216'** and the GFA **230'**. This message is followed by a Registration Reply message **271** back to the MN **262** via the same set of MIP nodes. The message **270** includes a Care of address field, which is typically populated by the MN **262**, using the GFA **230'** address advertised by the FA **216'**, this typically being the address of interface **230***a*' at the GFA **230'**. The message **270** installs the Care of address of the GFA **230'** into the HA **240** so that a MIP tunnel can be built for the MN **262** home address between the HA **240** and the GFA **230'**. Packets will then be delivered to the new GFA **230'** and messages **272** and **273** can then update the GFA **230'** with each new MN CoA as the MN changes FA **216'** under the same GFA **230'**. This procedure however fails if the address of the GFA **230'** on link **204'** is not reachable from the HA **240**. Alternative signaling as shown in FIGS. **3** to **5** and described next may instead be used, in accordance with the present invention.

FIG. **3** shows the dynamic allocation of the GFA **230** at the FA **216**, and the dynamic allocation of the GFA CoA at the GFA **230**. The FA **216** of FIG. **3** equates to the downstream node **102** of FIG. **1**, the GFA **230** of FIG. **3** equates to the intermediate node **104** of FIG. **1** and the HA **240** equates to the upstream node **106** of FIG. **1**. FIG. **3** is separated into an addressing domain 1 **201** including MN **262** and FA **216** and an addressing domain 2 **203** including HA **240**. GFA **230** is situated on a boundary **205** separating domains **201** and **203**. The process **130** of FIG. **1** equates to the MIP tunnel management between the HA **240** and the GFA **230** of FIG. **2**. Message **270** of FIG. **2** is broken up into hop by hop messages **270***a*, **270***b* and **270***c*. Message **110** of FIG. **1** equates to message **270***b* of FIG. **3** and message **120** of FIG. **1** equates to message **270***c* in FIG. **3**. The downstream interface address **104***a'* on the intermediate node equates to the GFA address in FIG. **3** whilst the upstream interface address **104***b'* of the intermediate node equates to the GFA CoA in FIG. **3**.

In step **301**, the FA **216** constructs a message **310** with the FA CoA address from domain 1 **201** and GFA address from domain 1 **201** advertised to MN **262** for movement detection purposes, and sends the message **310** to the MN **262**. The subsequent messaging of FIG. **3** is triggered when the MN **262** receives message **310** from FA **216**, which includes a new default GFA address, and which acts as a common identifier for any dynamically allocated GFA at that FA **216**. This means that if the MN **262** sees a new default GFA address then it must also acquire a new dynamically allocated GFA. Message **310** also includes the FA CoA of the FA **216** as is usual in MIP signaling.

Next, in step **303**, the MN **262** then sends Registration message **270***a* to the FA **216** including the Home address and HA **240** address of the MN **262**, with the intention of updating the GFA CoA for that home address at the HA **240**. The Registration message **270***a* includes a CoA field that can either be left blank by the MN **262** or can contain the default GFA address. In step **305**, FA **216** then dynamically allocates a GFA to the MN **262**, potentially with help from a policy server, e.g. a AAA server, that has an upstream interface that is reachable from the HA **240** included in the message **270***a*. Note that the HA is globally unique through the combination of the HA address and the realm part of the Network Address Identifier of the MN **262** that are included in message **270***a*. The GFA address and the FA CoA are then securely passed to the assigned GFA in message **270***b*. The FA CoA enables the GFA to build a tunnel to the present FA **216** of the MN **262** whilst the GFA address is included so it can be passed to the HA **240**. In step **307**, the GFA **230** then dynamically assigns a GFA CoA from an interface that is reachable from the HA **240** and then securely passes this address, along with the GFA address to the HA in message **270***c*. It does this by adding an extension to the MIP Registration message containing the GFA CoA, that is used instead of the CoA field which is either blank or includes the default GFA address, for construction of the MIP tunnel. The HA **240** can then build that tunnel towards the GFA CoA rather than towards the GFA address, because the GFA address is not itself reachable from the HA **240**. Next, in step **309**, the HA **240** includes the GFA and GFA CoA into the MIP Registration Reply message **271***a*, signs this message with the secret it shares with the MN **262**, and sends message **271***a* to the GFA **230**. In step **311**, the GFA **230** forwards the GFA and GFA CoA to the FA **216** in MIP Registration Reply Message **271***b*. Subsequently, in step **313**,

FA **216** forwards the GFA and GFA CoA to MN **262** in MIP Registration Reply Message **271***c*. Finally, in step **315**, MN **262** can then securely receive the GFA and GFA CoA which it can then include in subsequent MIP Registration messages **270** and **272** to refresh the installed MIP bindings in the HA and the GFA.

Note that, in other variations of the present invention, the GFA and GFA CoA can be passed back to the MN **262** in many other ways than via the HA, that make use of a different set of MIP security associations to sign the extension carrying those addresses. Note also that in another variation of the present invention, the GFA CoA can instead be dynamically assigned at the same time as the GFA is assigned at the FA, and the GFA CoA then passed in message **270***b* to the allocated GFA.

FIG. **4** repeats the elements (**262**, **216**, **230**, **240**), domains (**201**, **203**) and boundary **205** of FIG. **3**. Steps (**301'**, **303'**, **305'**, **307'**, **309'**, **311'**, **313'**, **315'**) of FIG. **4** equate to the steps (**301**, **303**, **305**, **307**, **309**, **311**, **313**, **315**) of FIG. **3**, respectively. Similarly, messages (**310'**, **270***a'*, **270***b'*, **270***c'*, **271***a'*, **271***b'*, **271***c'*) of FIG. **4** equate to messages (**310**, **270***a*, **270***b*, **270***c*, **271***a*, **271***b*, **271***c*) of FIG. **3**, respectively.

In addition, FIG. **4** shows the extensions used to carry the FA CoA, GFA CoA and the GFA address in messages **270'** and **271'**. The Hierarchical Foreign Agent Extension (HFAext) carries the FA CoA in message **270***b'* and carries the GFA CoA in message **270***c'* and messages **271'**. Note that if the GFA CoA is also assigned at the FA **216** then two HFAext are included in message **270***b'*, which means that either a flag bit is required in the HFAext to distinguish between the two addresses, or the FA CoA is signed with the secret shared between the FA **216** and the GFA **230** whilst the GFA CoA is signed with the secret shared between the FA **216** and the HA **240**, the type of signature therefore uniquely identifying the contents of each HFAext. The GFA address is carried in the Hierarchical Foreign Agent IP address extension (HFAIPext) in messages **270***b'*, **270***c'* to the HA **240**, and messages **271'** back to the MN **262**.

The steps and signaling of FIG. **4** are described below. In step **301'**, FA **216** adds the GFA address into the HFAIP extension, constructs message **310'** which includes FA CoA+HFAIPext, and sends message **310'** to MN **262**. This triggers the subsequent signaling described in FIG. **4**. Next, in step **303'**, MN **262** issues RREQ message **270***a'* to FA **216** with a blank CoA as the GFA CoA is not yet assigned. Then, in step **305'**, FA **216** includes FA CoA in the HFA extension, includes the dynamically assigned GFA in the HFAIP extension, signs both by the FA-GFA shared secret, and sends RREQ message **270***b'* including HFAIPext+HFAext to GFA **230**. Next, in step **307'**, GFA **230** replaces FA CoA in HFAext with a dynamically assigned GFA CoA, signs HFAIPext and HFAext with GFA-HA shared secret, and sends RREQ message **270***c'* including HFAIPext+HFAext to HA **240**. Upon reception of message **270***c'*, the process **130** is triggered at the HA **240** towards the GFA **230**. Additionally, the HA **240** extracts GFA and GFA CoA from message **270***c'*, signs them with the HA-MN shared secret, and sends them toward the MN **262** in the RREP message **271***a'* including HFAIPext+HFAext to GFA **230**. GFA **230**, in step **311'** forwards GFA and GFA CoA towards MN **262** via RREP message **271***b'* including HFAIPext+HFAext to FA **216**. Next, FA **216**, in step **313'**, forwards the GFA and GFA CoA to MN **262** via Message **271***c'* including HFAIPext+HFAext. Finally, in step **315'**, MN **262** retrieves GFA address for use in the HA field of the Regional Registration, and the GFA CoA for use as the CoA in Registration Requests to the HA.

FIG. **5** illustrates the additional processing associated with a dynamically assigned FA CoA and a dynamically assigned HA.

FIG. **5** repeats the elements (**262**, **216**, **230**, **240**) of FIG. **3**. FIG. **5** includes 3 addressing domains: an addressing domain 1 **5201**, an addressing domain 2 **5203**, and an addressing domain 3 **5207**. A boundary line **5205** separates domain 1 **5201** from domain 2 **5203**. A boundary line **5206** separates domain 1 **5201** from domain 3 **5207**. MN **262** is in addressing domain 3 **5207**. FA **216** is located on the boundary **5206** between addressing domain 3 **5207** and addressing domain 1 **5201**. GFA **230** is located on the other boundary **5205** separating addressing domain 1 **5201** from addressing domain 2 **5203**. HA **240** is located in addressing domain 2 **5203**. Steps (**501**, **503**, **505**, **507**, **509**, **511**, **513**, **515**) of FIG. **5** are similar to the steps (**301**, **303**, **305**, **307**, **309**, **311**, **313**, **315**) of FIG. **3**, respectively. Messages (**310**", **270***a*", **270***b*", **270***c*", **271***a*", **271***b*", **271***c*") of FIG. **5** are similar to messages (**310**, **270***a*, **270***b*, **270***c*, **271***a*, **271***b*, **271***c*) of FIG. **3**, respectively.

FIG. **5** shows two additional novel aspects of the invention: the dynamic allocation of a HA **240** and the case of the FA **216** straddling two addressing domains. Dynamic HA allocation is, without loss of generality, undertaken at the FA **216** potentially in conjunction with a policy server. The allocated HA address is then able to be used in selecting the GFA **230** address and the GFA CoA **104***b* as part of the same allocation procedure. If however the HA allocation is undertaken at the GFA **230** then only the GFA CoA **104***b* can be dynamically allocated based on the HA address **240** because of the GFA **230** will have be allocated at the FA **216** without knowledge of the yet to be assigned HA **240**. Assuming the HA address is allocated at the FA **216**, and having established the GFA **230**, then the FA **216** needs to pass to the GFA **230** in message **270***b*" the HA address in the Home Agent IP Address extension (HAIPext), or in a HFAIPext which includes flags or other indicators to differentiate between different types of addresses. The GFA **230** on receiving this HA address is then able to direct message **270***c*" to that identified HA address. The HA address is already returned to the MN **262** in the standard MIP RREP so the HAIPext is not needed to be included in messages **271**".

The second aspect of FIG. **5** is the addition of addressing domain 3 **5207** between the MN **262** and the FA **216**, such that the address included in message **310**" is now the FA address from domain 3 **5207**, and the FA **216** must then dynamically allocate a FA CoA from domain 1 **5201** for inclusion in message **270***b*" to facilitate the building of a MIP tunnel between the GFA **230** and the FA CoA at FA **216**. This is a second example of the applicability of FIG. **1**, where the MN **262** is the downstream node **102**, the GFA **230** is the upstream node **106**, and the FA **216** is the intermediate node **104** with FA address **104***a*' from domain 3 and FA CoA **104***b*' from domain 1 **5201**. Process **130** is then the tunnel construction between the GFA **230** and the FA **216**.

The steps and signaling of FIG. **5** are described below. In step **501**, for movement detection purposes, FA **216** advertises to MN **262** the FA address from domain 3 **5207** and the GFA address from domain 1 **5201** via FAA message **310**" including FA+GFA address. The subsequent messaging of FIG. **5** is triggered when the MN **262** receives message **310**" from FA **216**. In step **503**, MN **262** issues RREQ message **270***a*" to FA **216** with a blank CoA field because the GFA CoA is not yet known. Next, in step **505**, FA **216** dynamically assigns from domain 1 **5201**, potentially with AAA support, a FA CoA to the MN **262**, and dynamically assigns from domain 2 **5203**, potentially with AAA support, a HA **240** to the MN **262**. Then, FA **216** sends RREQ message **270***b*" including HA address in HAIPext to GFA **230**. Upon reception of message **230**, in step **507**, GFA **230** forwards the RREQ to HA **240** in RREQ message **270***c*". In step **509**, HA **240** sends RREP message **271***a*" to GFA **230** so that the MN **262** can ultimately learn the HA address from the RREP. Proceeding to step **511**, GFA **230** forwards RREP via message **271***b*" to FA **216**. Then, in step **513**, FA **216** signs with an MN-FA shared secret, and then returns the dynamically assigned FA CoA to the MN **262** via RREP message **271***c*" including FA CoA in HFAext. Finally, in step **515**, MN **262** retrieves from RREP message **271***c*" the FA CoA for use in the CoA field of Regional Registration and the HA address for use in subsequent RREQ messages to the HA **240**.

In various embodiments nodes described herein are implemented using one or more modules to perform the steps corresponding to one or more methods of the present invention, for example, signal processing, message generation and/or transmission steps. Thus, in some embodiments various features of the present invention are implemented using modules. Such modules may be implemented using software, hardware or a combination of software and hardware. Many of the above described methods or method steps can be implemented using machine executable instructions, such as software, included in a machine readable medium such as a memory device, e.g., RAM, floppy disk, etc. to control a machine, e.g., general purpose computer with or without additional hardware, to implement all or portions of the above described methods, e.g., in one or more nodes. Accordingly, among other things, the present invention is directed to machine-readable medium including machine executable instructions for causing a machine, e.g., processor and associated hardware, to perform one or more of the steps of the above-described method(s).

Numerous additional variations on the methods and apparatus of the present invention described above will be apparent to those skilled in the art in view of the above description of the invention. Such variations are to be considered within the scope of the invention. The methods and apparatus of the present invention may be, and in various embodiments are, used with CDMA, orthogonal frequency division multiplexing (OFDM), and/or various other types of communications techniques which may be used to provide wireless communications links between access nodes and mobile nodes. In some embodiments the access nodes are implemented as base stations which establish communications links with mobile nodes using OFDM and/or CDMA. In various embodiments the mobile nodes are implemented as notebook computers, personal data assistants (PDAs), or other portable devices including receiver/transmitter circuits and logic and/or routines, for implementing the methods of the present invention.

The above described methods and apparatus are exemplary. Numerous variations are possible while keeping within the scope of the invention.

What is claimed is:

1. A method of supporting disparate addressing plans in a wireless communication system, comprising:

receiving, at a downstream node configured to communicate in a first addressing domain, a registration request message from a mobile node visiting the first addressing domain, wherein the registration request message includes an upstream node address of an upstream node in a second addressing domain and an intermediate node downstream address indicator different from an intermediate node downstream address of an intermediate node;

dynamically allocating, at the downstream node, the intermediate node downstream address of the intermediate node to the mobile node in response to receiving the registration request message, wherein the intermediate node has an upstream interface that is reachable from the upstream node;

sending, from the downstream node, a first message including a first header and a first message body, the first header including the dynamically allocated intermediate node downstream address as the destination address of the first message, the first message body including at least one instruction and the dynamically allocated intermediate node downstream address, wherein the at least one instruction is configured to control the upstream node to interact with the intermediate node;

receiving, at the downstream node, a fourth message in response to the upstream node receiving a second message generated by the intermediate node based on the first message and the upstream node replying with a third message, the fourth message including a fourth message body that includes the dynamically allocated intermediate node downstream address and a dynamically allocated intermediate node upstream address used by the upstream node in invoking the at least one instruction, wherein the dynamically allocated intermediate node upstream address is in the second addressing domain; and

forwarding the dynamically allocated intermediate node downstream address and the dynamically allocated intermediate node upstream address to the mobile node.

2. The method of claim **1**, wherein receiving the registration request message including the intermediate node downstream address indicator further comprises receiving a blank field, or receiving a default intermediate node downstream address that acts as a common identifier for the dynamically allocated intermediate node downstream address.

3. The method of claim **2**, further comprising advertising the default intermediate node downstream address to the mobile node.

4. The method of claim **1**, wherein the dynamically allocated intermediate node downstream address is not reachable from the upstream node.

5. The method of claim **1**, further comprising dynamically allocating, at the downstream node, the dynamically allocated intermediate node upstream address.

6. The method of claim **1**, wherein the dynamically allocated intermediate node upstream address is dynamically allocated by the intermediate node from a selected interface that is reachable from the upstream node.

7. The method of claim **1**, wherein the dynamically allocated intermediate node upstream address is requested from an external policy server.

8. The method of claim **1**, further comprising dynamically selecting the intermediate node based on at least one of information about a type of communications process corresponding to the at least one instruction, information about the mobile node, information about a location of the mobile node, and information about a type and location of the upstream node.

9. The method of claim **1**, wherein the at least one instruction is an instruction to invoke a tunnel between the upstream node and the intermediate node.

10. The method of claim **1**, wherein the downstream node is a Mobile IP (MIP) foreign agent, the upstream node is a MIP home agent, and the intermediate node is a Gateway Foreign Agent, wherein the at least one instruction is an instruction used to control construction of a MIP tunnel between the MIP Home Agent and the Gateway Foreign Agent, wherein the registration request message comprises a MIP registration request, and wherein the third message comprises a registration reply message.

11. A non-transitory machine readable medium embodying machine executable instructions for supporting disparate addressing plans in a wireless communication system, comprising:

at least one instruction for receiving, at a downstream node configured to communicate in a first addressing domain, a registration request message from a mobile node visiting the first addressing domain, wherein the registration request message includes an upstream node address of an upstream node in a second addressing domain and an intermediate node downstream address indicator different from an intermediate node downstream address of an intermediate node;

at least one instruction for dynamically allocating the intermediate node downstream address of the intermediate node to the mobile node in response to receiving the registration request message, wherein the intermediate node has an upstream interface that is reachable from the upstream node;

at least one instruction for sending, from the downstream node, a first message including a first header and a first message body, the first header including the dynamically allocated intermediate node downstream address as the destination address of the first message, the first message body including at least one instruction and the dynamically allocated intermediate node downstream address, wherein the at least one instruction included in the first message body is configured to control the upstream node to interact with the intermediate node;

at least one instruction for receiving a fourth message in response to the upstream node receiving a second message generated by the intermediate node based on the first message and the upstream node replying with a third message, the fourth message including a fourth message body that includes the dynamically allocated intermediate node downstream address and a dynamically allocated intermediate node upstream address used by the upstream node in invoking the at least one instruction included in the first message body, wherein the dynamically allocated intermediate node upstream address is in the second addressing domain; and

at least one instruction for forwarding the dynamically allocated intermediate node downstream address and the dynamically allocated intermediate node upstream address to the mobile node.

12. A downstream node for supporting disparate addressing plans in a wireless communication system, comprising:

means for receiving, at the downstream node configured to communicate in a first addressing domain, a registration request message from a mobile node visiting the first addressing domain, wherein the registration request message includes an upstream node address of an upstream node in a second addressing domain and an intermediate node downstream address indicator different from an intermediate node downstream address of an intermediate node;

means for dynamically allocating the intermediate node downstream address of the intermediate node to the mobile node in response to receiving the registration request message, wherein the intermediate node has an upstream interface that is reachable from the upstream node;

means for sending, from the downstream node, a first message including a first header and a first message body, the first header including the dynamically allocated intermediate node downstream address as the destination address of the first message, the first message body including at least one instruction and the dynamically allocated intermediate node downstream address, wherein the at least one instruction is configured to control the upstream node to interact with the intermediate node;

means for receiving a fourth message in response to the upstream node receiving a second message generated by the intermediate node based on the first message and the upstream node replying with a third message, the fourth message including a fourth message body that includes the dynamically allocated intermediate node downstream address and a dynamically allocated intermediate node upstream address used by the upstream node in invoking the at least one instruction, wherein the dynamically allocated intermediate node upstream address is in the second addressing domain; and

means for forwarding the dynamically allocated intermediate node downstream address and the dynamically allocated intermediate node upstream address to the mobile node.

13. A downstream node for supporting disparate addressing plans in a wireless communication system, comprising:

a receiver configured to receive, at the downstream node configured to communicate in a first addressing domain, a registration request message from a mobile node visiting the first addressing domain, wherein the registration request message includes an upstream node address of an upstream node in a second addressing domain and an intermediate node downstream address indicator different from an intermediate node downstream address of an intermediate node;

a processor configured to dynamically allocate the intermediate node downstream address of the intermediate node to the mobile node in response to receiving the registration request message, wherein the intermediate node has an upstream interface that is reachable from the upstream node;

a transmitter configured to send, from the downstream node, a first message including a first header and a first message body, the first header including the dynamically allocated intermediate node downstream address as the destination address of the first message, the first message body including at least one instruction and the dynamically allocated intermediate node downstream address, wherein the at least one instruction is configured to control the upstream node to interact with the intermediate node;

wherein the receiver is further configured to receive, at the downstream node, a fourth message in response to the upstream node receiving a second message generated by the intermediate node based on the first message and the upstream node replying with a third message, the fourth message including a fourth message body that includes the dynamically allocated intermediate node downstream address and a dynamically allocated intermediate node upstream address used by the upstream node in invoking the at least one instruction, wherein the dynamically allocated intermediate node upstream address is in the second addressing domain; and

wherein the transmitter is further configured to forward the dynamically allocated intermediate node downstream address and the dynamically allocated intermediate node upstream address to the mobile node.

14. The downstream node of claim **13**, wherein the intermediate node downstream address indicator comprises a blank field, or a default intermediate node downstream address that acts as a common identifier for the dynamically allocated intermediate node downstream address.

15. The downstream node of claim **14**, wherein the transmitter is further configured to advertise the default intermediate node downstream address to the mobile node.

16. The downstream node of claim **13**, wherein the dynamically allocated intermediate node downstream address is not reachable from the upstream node.

17. The downstream node of claim **13**, wherein the processor is further configured to dynamically allocate the dynamically allocated intermediate node upstream address.

18. The downstream node of claim **13**, wherein the dynamically allocated intermediate node upstream address is dynamically allocated by the intermediate node from a selected interface that is reachable from the upstream node.

19. The downstream node of claim **13**, wherein the dynamically allocated intermediate node upstream address is requested from an external policy server.

20. The downstream node of claim **13**, wherein the processor is further configured to dynamically select the intermediate node based on at least one of information about a type of communications process corresponding to the at least one instruction, information about the mobile node, information about a location of the mobile node, and information about a type and location of the upstream node.

21. The downstream node of claim **13**, wherein the at least one instruction comprises an instruction to invoke a tunnel between the upstream node and the intermediate node.

22. The downstream node of claim **13**, wherein the downstream node is a Mobile IP (MIP) foreign agent, the upstream node is a MIP home agent, and the intermediate node is a Gateway Foreign Agent, wherein the at least one instruction is an instruction used to control construction of a MIP tunnel between the MIP Home Agent and the Gateway Foreign Agent, wherein the registration request message comprises a MIP registration request, and wherein the third message comprises a registration reply message.

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